Exposure to Toxic Waste Sites: An Investigative Approach

PAUL A. STEHR-GREEN, DrPH
JEFFREY A. LYBARGER, MD

Dr. Stehr-Green currently is an Epidemiologist in the Immunization Division, Center for Prevention Services at the Centers for Disease Control (CDC), Public Health Service. Formerly he was with the Division of Environmental Hazards and Health Effects, Center for Environmental Health and Injury Control, CDC. Dr. Lybarger is Chief of Epidemiology and Medicine Branch, Agency for Toxic Substances and Disease Registry, Public Health Service.

Tearsheet requests to Dr. Stehr-Green, Centers for Disease Control, 1600 Clifton Road, Atlanta, GA 30333.

Synopsis

Improper dumping and storage of hazardous substances and whether these practices produce significant human exposure and health effects are growing concerns. A sequential approach has been used by the Centers for Disease Control and the Agency for Toxic Substances and Disease Registry in investigating potential exposure to and health effects resulting from environmental contamination with materials such as heavy metals, volatile organic compounds, and pesticide residues at sites throughout the United States. The strategy consists of four phases: site evaluation, pilot studies of exposure or health effects, analytic epidemiology studies, and public health surveillance. This approach offers a logical, phased strategy to use limited personnel and financial resources of local, State, national, or global health agency jurisdictions optimally in evaluating populations potentially exposed to hazardous materials in waste sites. Primarily, this approach is most helpful in identifying sites for etiologic studies and providing investigative leads to direct and focus these studies. The results of such studies provide information needed for making risk-management decisions to mitigate or eliminate human exposures and for developing interventions to prevent or minimize health problems resulting from exposures that already have occurred.

THE U.S. POPULATION is becoming increasingly aware of environmental pollution attributed to indiscriminate dumping or improper storage of hazardous materials. A major concern about these hazardous waste sites is whether they produce significant human exposure and health effects. Although results of laboratory studies have shown that some hazardous chemicals can cause cancer, adverse reproductive outcomes, or other organ-specific damage in experimental animals, the health effects from low-level, long-term human exposure are not as well defined (*1*). In addition to experiencing possible physical health effects from chemicals, persons living near such sites often suffer severe psychological and economic stress. As the number of identified toxic waste sites grows, concerns and questions about public health increase, especially from people who live around those sites.

Humans can be exposed to hazardous materials in the soil, air, water, and food chain. Uptake of site-related chemicals from these contaminated environmental pathways then may occur through ingestion, inhalation, or absorption through the skin. The potential for exposure for persons living in communities near waste sites varies according to the extent and magnitude of environmental contamination and the type, frequency, and duration of human activities in contaminated areas. Identifying key environmental pathways of exposure, as well as understanding human activities and behaviors responsible for human exposure, is important.

We will describe a method used by the Centers for Disease Control (CDC) for selecting situations appropriate for studying exposures and health effects in communities near toxic waste sites. The goal of using this strategy is to acquire a more complete understanding of the ways in which humans are exposed to and affected by environmental contaminants. With that knowledge, appropriate public health interventions can be developed and implemented.

Difficulties in Environmental Evaluations

Methodological and logistical problems, as well as inadequate knowledge of underlying biological mechanisms, often hinder evaluation of the health impact of environmental contaminations. Quantifying exposure is one problem inherent in evaluating chronic community exposures to toxic wastes, especially at low exposure levels or for chemicals that

are metabolized rapidly and excreted. Documenting exposure to and uptake of a particular chemical (such as through detailed epidemiologic characterization by person, place, and time or by direct measurement of body burden) is an important procedure when conducting epidemiologic studies around waste sites. In 1985, data from the U.S. Environmental Protection Agency's (EPAs) Contract Laboratory Program were used to estimate the rates of occurrence and levels of concentration of 218 Priority Pollutants and hazardous substances found at waste sites in the United States (*2*). Contaminants most frequently detected at these sites included heavy metals (41.2 percent of the sites), organic volatiles (11.9 percent), inorganic ions (8.5 percent), organic semivolatiles (7.4 percent), pesticide residues (4.7 percent), and pesticide-associated organics (2.2 percent). These data indicate that many of the sites contained contaminants for which sensitive, replicable assays of human body burden are available. The potential for misclassification and dilution of observable effects increases in situations where putative toxicants cannot be measured because of inherently short biological half-lives in humans or lack of sufficiently sensitive and reliable analytic techniques, and when exposure risks cannot be adequately modelled. The overall result is that the statistical power of the study can be diminished.

Identifying effects from low-dose exposures presents another problem. Often, no toxicologic information relevant to long-term exposures in humans is available, necessitating reliance on experimental data from animals or extrapolation from high-dose intoxications such as poisonings or exposures in industrial settings in humans. Because of differences between species or the uncertainties of extrapolating effects from high-dose to low-dose settings, these sources of data may be inappropriate for evaluating long-term, low-level exposures in residential settings. Even with identified end points of disease, problems of low incidence, long latency periods, and the silent development of disease can limit an investigator's ability to link pathologic changes to specific exposures. Nonspecific clinical signs and symptoms also make measuring ongoing effects difficult. Nonetheless, we must consider all these factors and acknowledge the probable multifactorial nature of the adverse health effects under investigation.

Investigative Approach

The approach we use follows a logical progression of more detailed investigative activities. Decisions to initiate more sophisticated activities are based on evidence of increased risks for public health during previous phases. The essential phases of this strategy are as follows:

Phase 1—Site evaluation. The site evaluation consists of a comprehensive review of environmental data from waste sites and environmental pathways to which people may be exposed, correlating the findings with demographic data for the area. A comprehensive environmental sampling plan should collect information from which the extent and degree of human exposure risks to hazardous materials can be estimated and assist with planning for remedial action. The site evaluation plan directs the sampling of environmental media along all migration pathways of contaminants to determine whether hazardous materials can be identified at locations of human contact. Concurrently, population demographics and patterns of waste site-related land use are evaluated.

Data on environmental sampling (for example, contaminant levels measured in surface and ground water, soil, and food chain) that have been collected for the purpose of site characterization or remedial planning, or both, may be available from the Environmental Protection Agency or State environmental agencies. Population data often can be obtained from census reports and municipal records (for example, files of tax assessors or in city planning offices). Based on the review of these data, the potential hazard posed by the site can be assessed. Sites with the greatest potential for human exposure to areas of contamination are selected for pilot studies. This site characterization phase is called a "Health Assessment" under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA or Superfund), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA).

Phase 2—Pilot studies. The pilot study is a preliminary evaluation to determine if sufficient evidence of exposure or occurrence of adverse health effects is present to initiate an analytic epidemiologic study; this study is not performed to determine causality. Pilot studies can use any of three predominant designs:

1. In an exposure study, persons at highest risk for exposure at sites chosen in Phase 1 are identified through data obtained from site-specific questionnaire surveys and available environmental sam-

pling data. Persons are selected for inclusion in these studies by using ecological models of exposure that incorporate key elements of person, place, and time. Tests are performed for elevated levels of some biomarker of exposure and the results compared with a reference group or with available national information.

2. The disease and symptom prevalence study involves collecting self-reported information by questionnaire. These data should be verified with objective medical records or clinical examinations whenever possible. The prevalence of self-reported diseases or symptoms is then compared with a reference group or other local or national information.

3. A cluster investigation is initiated after identifying several case reports with ostensibly common features regarding place and time of occurrence. The investigation attempts to determine if the cluster actually represents an incidence of disease distinct from background rates that can be linked in place and time to a potential source of exposure.

Phase 3–Analytic epidemiologic studies. Analytic epidemiologic studies are conducted to provide definitive information about the causal relationship between exposure to hazardous materials and the occurrence of adverse health effects. Hypotheses generated by the preceding pilot study may lead to improved knowledge of the type and extent of exposure and the health outcome(s) to be measured. These are required to conduct rigorous analytic epidemiologic studies that use traditional cohort, case-control, or cross-sectional designs.

Phase 4–Public health surveillance. Public health surveillance includes long-term followup of persons identified as either exposed to hazardous substances higher than background levels or diagnosed with specific diseases or physiologic changes thought to be predictive of future development of disease. A primary advantage of surveillance is that it accommodates some of the previously discussed limitations inherent in conducting epidemiologic investigations (for example, latency intervals for development of disease which require lengthy periods of observation to determine if adverse health effects are occurring at rates higher than expected). Through this process, information on the natural history of exposure-related diseases is accumulated and long-term risks for human health are quantified. Second, through followup activities, public health practitioners can provide ongoing or intermittent community education and medical monitoring. The CERCLA provisions allow for the development of registries to assist with these longitudinal research and service activities. Further, the surveillance provisions of CERCLA direct that, as determined by the Administrator of the Agency for Toxic Substances and Disease Registry (ATSDR), medical monitoring may be performed.

This investigative approach provides a stepwise, logical process that identifies sites suitable for more rigorous studies and investigative leads for subsequent studies. This triaging approach also allows optimal use of limited personnel and financial resources in a local or State health department as well as at a national or global level. This logical, straightforward approach can guide communities and public officials toward more realistic expectations of the timeliness, completeness, and potential benefits or deficiencies of planned studies. This approach not only enhances confidence and support of the population, but provides communities with a foundation for making important public decisions on appropriate public health interventions and remedial actions.

Discussion

The Centers for Disease Control (CDC) and ATSDR have used this strategy for assessing the potential impact on public health of a wide range of environmental contaminants. These contaminants include the following:

- lead (two unpublished internal reports, July 1986: (*a*) CDC, EPA, Lewis and Clark County Health Department, Montana Department of Health and Environmental Sciences; (*b*) CDC, EPA, Panhandle District Health Department, Idaho Department of Health and Welfare.)
- arsenic (unpublished CDC study, EPI-85-36-2, August 1985)
- volatile organic compounds such as benzene and trichloroethylene (unpublished CDC study, EPI-82-90-2, August 1983)
- pesticide residues (heptachlor and chlordane) (*3*)
- chlorinated hydrocarbon compounds (polychlorinated biphenyls—PCBs) (*4*)
- 2,3,7,8-tetrachlorodibenzodioxin (TCDD) (*5–8*).

Experience acquired in these studies confirms the need for public health officials and concerned citizens to consider all aspects of the traditional epidemiologic triad of "agent, host, and environment" when evaluating potential risks to human health from high contamination levels associated

with dump sites for hazardous waste. The following factors should be considered:

1. the physical characteristics of waste site materials;
2. physical and behavioral factors affecting absorption of these chemicals in biological systems;
3. characteristics of populations at risk of exposure (especially the presence of sensitive human populations);
4. access to, frequency, duration, and use of contaminated areas;
5. the spread of waste site materials via different environmental pathways. Unless significant exposure to and uptake of chemicals actually occur, adverse health outcomes cannot be attributed to chemicals at waste sites.

To date, we have not evaluated the sensitivity, specificity, and predictive value of this phased investigative process. As a result, some limitations can be anticipated. First, this process may not identify some significant public health problems that require more detailed study as those sites are screened out in Phase I. This provides an argument for reassessing the need for followup evaluations as new information on sites becomes available. Second, using this approach does not guarantee that increased incidence of health effects (even if present) attributed to waste site chemicals will be detected at sites chosen for Phase 3 or 4 studies. The most serious methodological problems that apply to all of these studies (especially the smaller pilot studies) are small sample sizes, introduction of potentially damaging recall biases, and the possibility of misclassifying the exposure status of individuals. Such errors mitigate the detection of small differences attributable to exposures or lead to spurious findings and inconclusive investigations. In such settings, acquiring information necessary for the development of appropriate public health interventions may be limited to using supplementary methods, such as risk-assessment modeling techniques. Finally, all investigations may be limited by public perceptions or policy concerns and the willingness of local residents to participate in investigations. Initiation of timely, responsive, and accurate public health education activities is an important adjunct to any investigation.

Conclusions

Factors that determine the exposure to and resulting health risks posed by any waste site are likely to be unique to that site. The systematic approach we have discussed can contribute, however, to a more complete understanding of the relative importance of potentially critical behavioral factors such as local patterns of native fish consumption or scavenging activities at waste sites, land use (for example, siting of residential and recreational areas), and environmental characteristics such as migration and deposition of contaminants. Collecting this information may be useful for discerning patterns of exposure, uptake, and pathogenesis that are characteristic of all toxic waste sites.

Epidemiologic studies can yield valuable information on the etiologic role that exposures to toxic wastes play in the development of human disease. Supplementary methods, such as risk-assessment modeling techniques, are also valuable for evaluating health risks, especially in selected situations of environmental contamination when exposure, chemical uptake, long-term deposition in the body, and health effects cannot directly be measured. Together these approaches contribute information needed to make risk-management decisions that can minimize health problems that result from past exposures and prevent future exposures.

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